Modelling the impact of weather on road casualty statistics

Introduction

This document provides further information on the methodology used to quantify the impact of temperature and rainfall on the number of road casualties in order to produce a weather-adjusted road casualty series.

Weather patterns have been used to help explain year-on-year and quarterly changes in road casualty numbers in recent publications (see here). For the Reported Road Casualties Great Britain: 2013 Annual Report a chapter was included to summarise the literature available on weather impacts on road accidents and casualties as well as discussing the main weather trends seen since 2010 and their likely impact on road casualties (see here). This article sets out the methodology that has been used to quantify the impact of temperature and rainfall on the number of road casualties in order to produce a weather-adjusted road casualty series.

The Department for Transport volunteered to be part of a cross government group looking at how the weather impacts on different types of statistical series could be assessed. As part of this work a guide to modelling the impact of weather and climate on official statistics has been produced by the ONS Time Series Analysis Branch (see here). As part of this modelling guide a case study on the impact of temperature on the monthly number of killed or seriously injured vulnerable road users (pedestrians, pedal cyclists and motorcyclists) was undertaken. Detailed results of this work can be found on page 74 of the modelling guide and are summarised in the section below.

Assessing the impact of temperature on killed or seriously injured vulnerable road users

Research suggests that higher temperatures may increase the number of vulnerable road users on the road (particularly in the summer months) leading to an increase in their exposure to accidents. This increased exposure is likely to increase the number of these users that are killed or seriously injured during these periods of higher temperature. The ONS case study aimed to test this hypothesis by modelling how the temperature impacts the number of killed or seriously injured vulnerable road users.

Monthly totals for killed or seriously injured vulnerable road users over 1979 to 2012 were sourced from the STATS19 system which contains details of personal-injury road accidents on public roads (including footways) in Great Britain, which became known to the police. The weather data used in this analysis was the monthly mean UK temperature series, one of the monthly climate series available from the Met Office (available here). regARIMA modelling was used to test in which months there is an effect of temperature on the number of killed or seriously injured vulnerable road users with the effect also estimated for each month (more detail on regARIMA modelling is available in the modelling guide: here).

The final model found statistically significant positive effects (i.e. above average temperatures leading to increases, below average temperatures leading to decreases) for all months of the year except for August, September and November. The effect varies between months, from a 1°C increase in temperature above average (all else being equal) resulting in an additional 27 killed or seriously injured vulnerable road users in October to an additional 95 in April. Similarly, according to the model a 1°C decrease in temperature below average results in between 27 fewer killed or seriously injured vulnerable road users in October and 95 fewer in April. The effect has been modelled as linear meaning that, for example in October each 1°C increase in temperature above average will see an additional 27 killed or seriously injured vulnerable road users, so if an October is 2°C warmer than the average temperature for October, then all else being equal, there will be an additional 54 more killed or seriously injured vulnerable road users than if the temperature had been average.

regARIMA final model output

Variable	Parameter Estimate	Standard Error	t-value
User-defined			
jan	50.9173	15.94284	3.19
feb	48.7394	13.78862	3.53
mar	87.1861	16.94539	5.15
apr	95.2455	16.88851	5.64
may	77.6860	20.57438	3.78
jun	81.7293	22.18659	3.68
jul	54.0150	17.92910	3.01
oct	27.2009	13.12435	2.07
dec	61.8352	12.62485	4.90

Assessing the impact of temperature and rainfall on all road user casualties

Introduction

The Met Office also publish UK rainfall figures as part of their monthly climate series (available here). It was decided to test the impact of both the mean UK temperature and UK rainfall in each month on the number of casualties (fatal, serious and slight) for each of the following road user groups: vulnerable road users (pedestrians, pedal cyclists and motorcyclists) and car occupants. The impact on other vehicle occupants (bus and coach occupants, goods vehicle occupants and other vehicles) was also tested, but very few statistically significant effects of either temperature or rainfall were found. Furthermore, other vehicle occupants make up a very small proportion of fatalities, serious and slight injuries so adjusting these figures would have very little impact on the overall figures. It was therefore decided to only adjust the casualty figures for vulnerable road users and car occupants.

Data used for the analysis

Road casualty data

Information on the severity of injuries sustained by different types of road users in reported personal injury road accidents is available from the STATS19 system. The geographical coverage of the data set is Great Britain. To use the regARIMA approach, a time series of counts is required. For this analysis monthly time series of killed, seriously injured and slightly injured casualties over January 1979 to December 2014 were used for each road user group (pedestrians, pedal cyclists, motorcyclists and car occupants). This resulted in twelve models i.e. three models (representing fatalities, serious injuries and slight injuries) for each road user group (pedestrians, pedal cyclists, motorcyclists and car occupants). The 2014 monthly data used in the analysis is shown below for each road user type.

Reported road casualties by road user type and month: GB, 2014

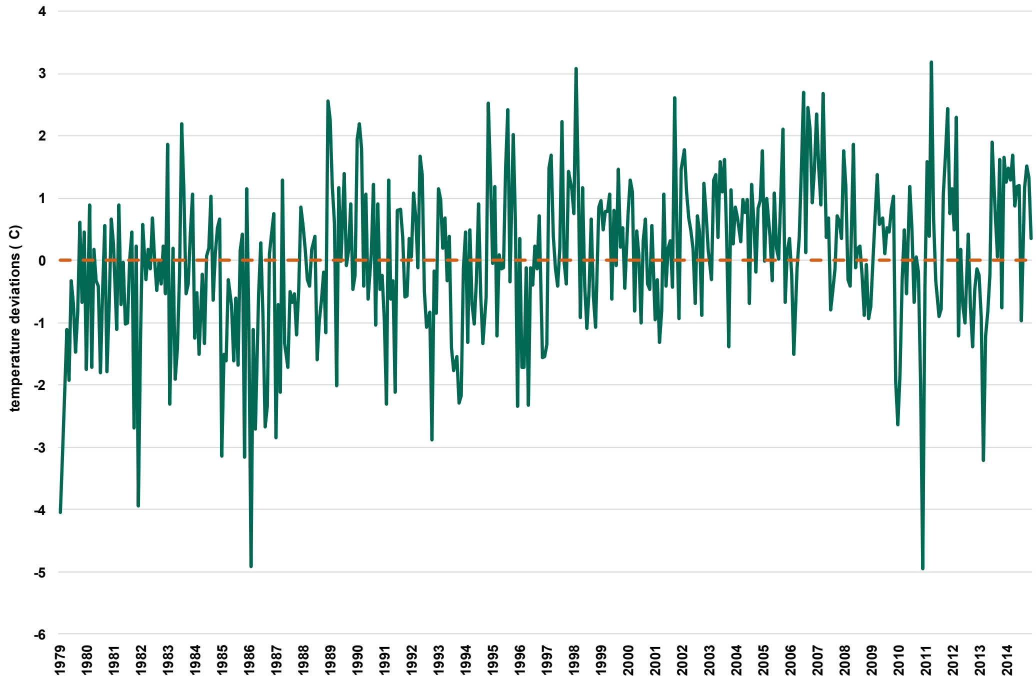
	Car Occupant				Pedestrian				Pedal Cyclist				Motorcycle Rider/Passenger			
Month	Killed	Serious	Slight	Total	Killed	Serious	Slight	Total	Killed	Serious	Slight	Total	Killed	Serious	Slight	Total
Jan	69	697	8,881	9,647	35	492	1,904	2,431	8	222	1,303	1,533	13	276	956	1,245
Feb	52	622	8,128	8,802	30	430	1,564	2,024	12	180	1,103	1,295	16	259	888	1,163
Mar	53	670	8,666	9,389	37	439	1,692	2,168	6	248	1,404	1,658	29	396	1,143	1,568
Apr	69	633	8,321	9,023	25	360	1,354	1,739	12	254	1,276	1,542	29	473	1,139	1,641
May	56	640	9,047	9,743	27	368	1,506	1,901	6	292	1,534	1,832	34	521	1,325	1,880
Jun	74	663	8,669	9,406	26	407	1,525	1,958	10	377	1,804	2,191	42	564	1,390	1,996
Jul	63	651	9,201	9,915	32	401	1,475	1,908	11	395	2,004	2,410	38	581	1,438	2,057
Aug	64	699	9,454	10,217	27	350	1,257	1,634	16	303	1,510	1,829	34	518	1,269	1,821
Sep	57	600	7,755	8,412	29	401	1,448	1,878	13	358	1,730	2,101	52	531	1,416	1,999
Oct	71	706	9,566	10,343	39	450	1,730	2,219	3	313	1,677	1,993	21	486	1,503	2,010
Nov	74	742	9,764	10,580	66	477	1,925	2,468	8	254	1,417	1,679	13	393	1,265	1,671
Dec	95	712	9,246	10,053	73	488	1,859	2,420	8	205	1,011	1,224	18	291	1,006	1,315
TOTAL	**797**	**8,035**	**106,698**	**115,530**	**446**	**5,063**	**19,239**	**24,748**	**113**	**3,401**	**17,773**	**21,287**	**339**	**5,289**	**14,738**	**20,366**

Met office data

The weather data selected for this analysis was mean UK temperature and UK rainfall data by month from the monthly climate series (see here). The monthly climate series are available for the UK but not for Great Britain. An alternative would be to construct weather data for Great Britain using weather data available for sub-regions of the UK. However, it was felt that the UK data would be a good measure for Great Britain so UK Met Office data was used.

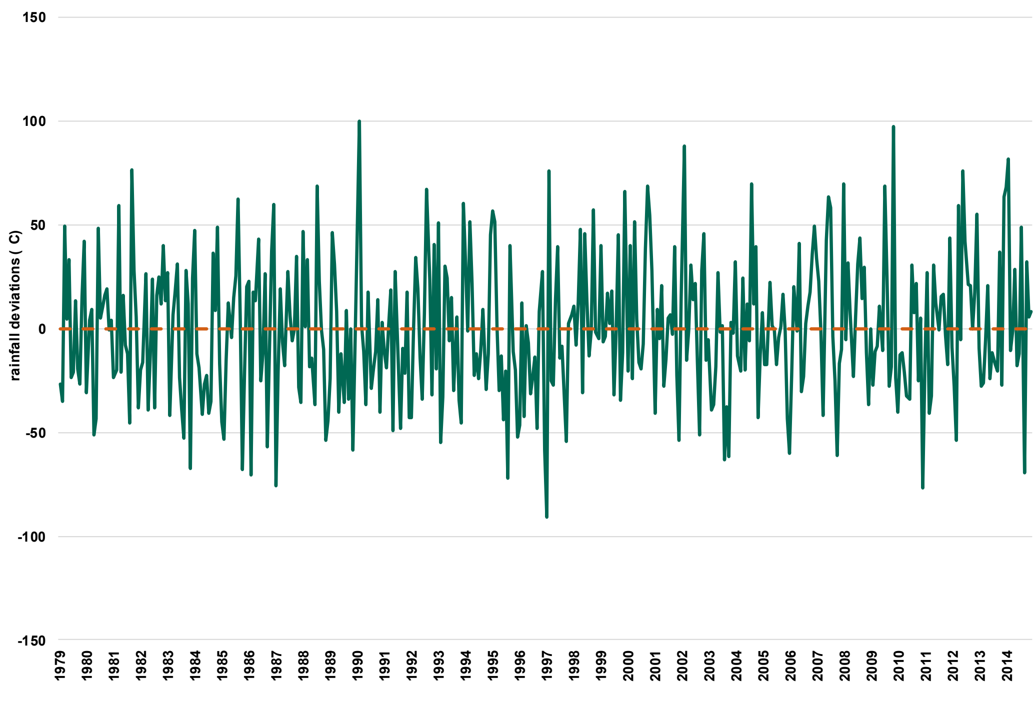
For each month, the average of all of the mean monthly UK temperatures (downloaded from here) was calculated over the period January 1979 to July 2015. This was then subtracted from the mean UK temperature in that month to produce a time series of temperature deviations from the long-run monthly average. This is plotted in the chart below (chart 1). This shows that colder than average temperatures tend to be more extreme in terms of the temperature deviation, than warmer than average temperatures.

Chart 1: Time series of temperature deviations from long-run monthly average between January 1979 and July 2015



Similarly, the average level of rainfall over the period January 1979 to July 2015 was calculated for each month. This was then subtracted from the monthly rainfall level in each month over the period to produce a time series of rainfall deviations from the long-run monthly average (chart 2).

Chart 2: Time series of rainfall deviations from long-run monthly average between January 1979 and July 2015



Time series modelling

It was decided to use regARIMA modelling to test the effect of temperature and the level of rainfall on the number of killed, seriously injured and slightly injured casualties for the following road user groups: pedestrians, pedal cyclists, motorcyclists and car occupants. This resulted in twelve regARIMA models.

Two sets of weather regressors were included in the modelling. Temperature regressors were calculated as the deviation in temperature in a given month from the average temperature in that month over the period January 1979 to July 2015. Rainfall regressors were calculated as the deviation in rainfall in a given month from the average rainfall in that month over the period January 1979 to July 2015.

The time series being analysed is quite long so the modelling has been carried out on a reduced span of data. In the 1980s the differences between the peaks and troughs in casualties is much larger than in more recent years. Therefore the time series from 1991 to 2014 has been analysed. The order of each ARIMA model was selected in X-13ARIMA-SEATS. Results are presented below.

Each model was run initially with all regressors included. Backwards selection was then used to select a model with a set of regressors which were all statistically significant. Backwards selection is an iterative process where of all of the regressors which are not found to be statistically significant, the least significant is removed. The model is then refitted and the process is run again until all remaining regressors are statistically significant. The resulting regressors in the final models and their estimated coefficients can be found below.

The temperature and rainfall effects have been modelled as linear. This means that the temperature and rainfall effect increases linearly with the temperature and rainfall deviation. For example, it is estimated that a March in which temperature is 1 °C higher than average leads to 38 more seriously injured motorcyclists than if temperature is average (see below), so if March is 2 °C higher than the average temperature for March, then all else being equal, there will be an additional 76 seriously injured motorcyclists. However, for extreme deviations the assumption of linearity may not hold e.g. it is unlikely that if a March was 6 °C above average that this would lead to 228 more seriously injured motorcyclists (6 x 38). However, extreme deviations are rare so the assumption of linearity is likely to be reasonable e.g. the majority of temperature deviations are between -2 °C to 2 °C from the average (see chart 1). Unlike temperature, rainfall cannot take negative values so the maximum deviation of rainfall below average in any month is capped at the long run average rainfall for that month (which would be achieved if rainfall in the month was 0 mm).

The estimated temperature and rainfall effects for each road user type (pedestrians, pedal cyclists, motorcyclists and car occupants) are summarised in the tables below for each severity. These estimated effects have been used to produce the weather-adjusted road casualty series (see below).

Killed pedestrians

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0,1,1)(0,1,1)12 regARIMA model. A log transformation was applied to the series.

Variable	Parameter estimate	Standard Error	t-value
Feb_rain	0.002	0.00077	2.58
Dec_rain	0.0018	0.00068	2.62

The final model includes rainfall regressors for the months of February and December. The model suggests that as rainfall increases in these months, the number of killed pedestrians increases. The largest effect is found for the February regressor with an estimated coefficient of 0.002 which implies that if the rainfall in February is 1 mm higher than average this will increase the number of killed pedestrians in February by about 0.2%. All else being equal, if rainfall in February is 1 mm below average this will decrease the number of killed pedestrians by about 0.2%. Given that only February and December were statistically significant for rainfall, the annual weather-adjusted series for killed pedestrians does not change much from the original series.

Seriously injured pedestrians

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0,1,2)(0,1,1)12 regARIMA model. A log transformation was applied to the series.

Variable	Paramater estimate	Standard error	t-value
mar_temp	0.0274	0.00938	2.92
may_temp	0.0284	0.01341	2.12
dec_temp	0.0422	0.00826	5.11
jan_rain	0.0013	0.00029	4.48
feb_rain	0.0008	0.00032	2.45

The final model includes temperature regressors for March, May and December and rainfall regressors for the months of January and February. The model suggests that as temperature increases in March, May and December, the number of seriously injured pedestrians increases. The largest effect is found for the December regressor with an estimated coefficient of 0.042 which implies that if the temperature in December is 1 °C higher than average this will increase the number of seriously injured pedestrians in December by about 4%. The model suggests that as rainfall increases in January and February, the number of seriously injured pedestrians increases. According to the model, if rainfall in January and February is 1 mm above average then there will be an increase in the number of seriously injured pedestrians by about 0.1%.

Slightly injured pedestrians

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0,1,1)(0,1,1)12 regARIMA model. No transformation was applied to the series.

Variable	Parameter estimate	Standard error	t-value
mar_temp	36.80	15.22	2.42
jan_rain	2.72	0.47	5.82
nov_rain	1.76	0.59	2.96
dec_rain	2.40	0.45	5.29

The final model includes temperature regressors for March and rainfall regressors for the months of January, November and December. The model suggests that as temperature increases in March, the number of slightly injured pedestrians increases. According to the model, if the temperature in March is 1 °C higher than average there will be an additional 37 slightly injured pedestrians. The model suggests that as rainfall increases in January, November and December, the number of slightly injured pedestrians increases. The largest effect is found for the January regressor with an estimated coefficient of 2.720 which implies that if the rainfall in January is 1 mm higher than average this will result in an additional 3 slightly injured pedestrians.

Killed pedal cyclists

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0,1,1)(0,1,1)12 regARIMA model. A log transformation was applied to the series.

Variable	Parameter estimate	Standard error	t-value
jan_temp	0.117	0.057	2.060
mar_temp	0.103	0.050	2.070
dec_temp	0.098	0.044	2.230
apr_rain	-0.007	0.002	-2.930

The final model includes temperature regressors for January, March and December and a rainfall regressor for April. The model suggests that as temperature increases in January, March and December, the number of killed pedal cyclists increases. The largest effect is found for the January regressor with an estimated coefficient of 0.117 which implies that if the temperature in January is 1 °C higher than average this will increase the number of killed pedal cyclists in January by about 11.7%. The model suggests that as rainfall increases in April, the number of killed pedal cyclists decreases. According to the model, if rainfall in April is 1 mm above average then there will be a decrease in the number of killed pedal cyclists by about 0.7%.

Seriously injured pedal cyclists

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0 1 1)(0 1 1)12 ARIMA model. A log transformation was applied to the series.

Variable	Parameter estimate	Standard error	t-value
jan_temp	0.077	0.016	4.760
feb_temp	0.075	0.014	5.390
mar_temp	0.069	0.014	4.910
jun_temp	0.082	0.022	3.710
jul_temp	0.057	0.017	3.320
sep_temp	0.045	0.022	2.020
dec_temp	0.087	0.012	7.000
apr_rain	-0.004	0.001	-5.880
may_rain	-0.002	0.001	-2.740

The final model includes temperature regressors for January, February, March, June, July, September and December and rainfall regressors for April, and May. The model suggests that as temperature increases in January, February, March, June, July, September and December, the number of seriously injured pedal cyclists increases. The largest effect is found for the December regressor with an estimated coefficient of 0.087 which implies that if the temperature in December is 1 °C higher than average this will increase the number of seriously injured pedal cyclists in December by about 8.7%. The model suggests that as rainfall increases in April and May, the number of seriously injured pedal cyclists decreases. According to the model, if rainfall in April is 1 mm above average then there will be a decrease in the number of killed pedal cyclists by about 0.4%.

Slightly injured pedal cyclists

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0 1 1)(0 1 1)12 ARIMA model. No transformation was applied to the series.

Variable	Parameter estimate	Standard error	t-value
jan_t	67.195	16.064	4.180
feb_t	54.699	13.488	4.060
mar_t	84.208	13.487	6.240
apr_t	91.067	15.698	5.800
may_t	89.489	20.206	4.430
jun_t	82.380	25.746	3.200
jul_t	89.827	19.816	4.530
aug_t	63.912	19.527	3.270
sep_t	59.573	22.768	2.620
nov_t	39.695	13.835	2.870
dec_t	61.451	12.373	4.970
jun_r	-2.567	0.647	-3.970
jul_r	-2.220	0.897	-2.470
aug_r	-1.699	0.562	-3.020

The final model includes temperature regressors for January, February, March, April, May, June, July, August, September, November and December and rainfall regressors for the months of June, July and August. The model suggests that as temperature increases in January, February, March, April, May, June, July, August, September, November and December, the number of slightly injured pedal cyclists increases. According to the model, if the temperature in April is 1 °C higher than average there will be an additional 91 slightly injured pedal cyclists. The model suggests that as rainfall increases in June, July and August, the number of slightly injured pedal cyclists decreases. The largest effect is found for the June regressor with an estimated coefficient of -2.567 which implies that if the rainfall in June is 1 mm higher than average this will result in 3 fewer slightly injured pedal cyclists.

Killed motorcyclists

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0 1 1)(0 1 1)12 ARIMA model. A log transformation was applied to the series.

Variable	Parameter estimate	Standard error	t-value
jan_temp	0.099	0.036	2.710
feb_temp	0.164	0.031	5.240
mar_temp	0.123	0.032	3.820
apr_temp	0.141	0.036	3.900
aug_temp	0.117	0.041	2.850
sep_temp	0.114	0.048	2.380
dec_temp	0.112	0.028	3.940
mar_rain	-0.006	0.002	-3.540
jun_rain	-0.004	0.001	-2.730
sep_rain	-0.005	0.001	-3.520
nov_rain	-0.004	0.001	-2.950

The final model includes temperature regressors for January, February, March, April, August, September and December and rainfall regressors for March, June, September and November. The model suggests that as temperature increases in January, February, March, April, August, September and December, the number of killed motorcyclists increases. The largest effect is found for the February regressor with an estimated coefficient of 0.164 which implies that if the temperature in February is 1 °C higher than average this will increase the number of killed motorcyclists in February by about 16.4%. The model suggests that as rainfall increases in March, June, September and November, the number of killed motorcyclists decreases. According to the model, if rainfall in March is 1 mm above average then there will be a decrease in the number of killed motorcyclists by about 0.6%.

Seriously injured motorcyclists

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0,1,1)(0,1,1)12 regARIMA model. No transformation was applied to the series.

Variable	Parameter estimate	Standard error	t-value
feb_temp	19.179	6.040	3.180
mar_temp	37.978	6.119	6.210
apr_temp	30.364	9.012	3.370
may_temp	22.535	9.007	2.500
oct_temp	18.603	5.971	3.120
dec_temp	19.865	5.479	3.630
mar_rain	-0.973	0.325	-2.990
apr_rain	-1.225	0.386	-3.180
may_rain	-1.117	0.325	-3.440
jun_rain	-1.402	0.250	-5.600
jul_rain	-1.607	0.329	-4.880
aug_rain	-0.914	0.235	-3.890
sep_rain	-1.044	0.266	-3.930
oct_rain	-0.657	0.225	-2.920

The final model includes temperature regressors for February, March, April, May, October and December and rainfall regressors for March, April, May, June, July, August, September, and October. The model suggests that as temperature increases in February, March, April, May, October and December, the number of seriously injured motorcyclists increases. The largest effect is found for the March regressor with an estimated coefficient of 37.978 which implies that if the temperature in March is 1 °C higher than average this will lead to an additional 38 seriously injured motorcyclists. The model suggests that as rainfall increases in March, April, May, June, July, August, September and October, the number of seriously injured motorcyclists decreases. The largest effect is found for the July regressor with an estimated coefficient of -1.607 which implies that if the rainfall in July is 1 mm higher than average this will lead to 2 fewer seriously injured motorcyclists.

Slightly injured motorcyclists

Initially a (0 1 1)(0 1 1) ARIMA model with no transformation was selected. However, due to failure of the model diagnostics a (0 1 2)(0 1 1) ARIMA model with log transformation was used.

Variable	Parameter estimate	Standard error	t-value
mar_temp	0.068	0.010	7.030
apr_temp	0.063	0.011	5.820
may_temp	0.030	0.014	2.170
jul_temp	0.038	0.012	3.270
dec_temp	0.043	0.012	3.660
mar_rain	-0.002	0.000	-3.060
jun_rain	-0.001	0.000	-3.200
aug_rain	-0.001	0.000	-2.620

The final model includes temperature regressors for March, April, May, July and December and rainfall regressors for March, June and August. The model suggests that as temperature increases in March, April, May, July and December, the number of slightly injured motorcyclists increases. The largest effect is found for the March regressor with an estimated coefficient of 0.068 which implies that if the temperature in March is 1 °C higher than average this will increase the number of slightly injured motorcyclists in March by about 6.8%. The model suggests that as rainfall increases in March, June and August, the number of slightly injured motorcyclists decreases. The largest effect is found for the March regressor with an estimated coefficient of -0.0015 which implies that if the rainfall in March is 1 mm higher than average this will decrease the number of slightly injured motorcyclists in March by about 0.15%.

Killed car occupants

No statistically significant effect of temperature or rainfall was found on car occupant fatalities in any month. Therefore, the monthly car occupant fatalities have not been adjusted.

Seriously injured car occupants

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0,1,1)(0,1,1)12 regARIMA model. A log transformation was applied to the series.

Variable	Paramter estimate	Standard error	t-value
dec_temp	0.025	0.008	3.310
apr_rain	0.001	0.000	2.560
jun_rain	0.002	0.000	4.450
jul_rain	0.001	0.000	2.260
aug_rain	0.001	0.000	3.420
sep_rain	0.001	0.000	3.130
nov_rain	0.001	0.000	3.270

The final model includes a temperature regressor for December and rainfall regressors for April, June, July, August, September and November. The model suggests that as temperature increases in December, the number of seriously injured car occupants increases. The December temperature regressor with an estimated coefficient of 0.025 implies that if the temperature in December is 1 °C higher than average this will increase the number of seriously injured car occupants in December by about 2.5%. The model suggests that as rainfall increases in April, June, July, August, September and November, the number of seriously injured car occupants increases. The largest effect is found for the June regressor with an estimated coefficient of 0.002 which implies that if the rainfall in June is 1 mm higher than average this will increase the number of seriously injured car occupants in June by about 0.2%.

Slightly injured car occupants

The automatic selection of the order of the ARIMA model in X-13ARIMA-SEATS was an (0,1,1)(0,1,1)12 regARIMA model. A log transformation was applied to the series.

Variable	Parameter estimate	Standard error	t-value
feb_temp	-0.015	0.007	-2.210
apr_temp	0.027	0.009	2.980
oct_temp	-0.015	0.006	-2.590
nov_temp	-0.017	0.006	-2.660
feb_rain	0.001	0.000	3.840
mar_rain	0.001	0.000	2.670
apr_rain	0.002	0.000	5.520
may_rain	0.001	0.000	4.230
jun_rain	0.001	0.000	5.500
jul_rain	0.001	0.000	2.960
aug_rain	0.001	0.000	3.400
sep_rain	0.002	0.000	5.770
oct_rain	0.001	0.000	2.950
nov_rain	0.001	0.000	3.790
dec_rain	0.001	0.000	2.600

The final model includes temperature regressors for February, April, October and November and rainfall regressors for February, March, April, May, June, July, August, September, October, November and December. The model suggests that as temperature increases in April, the number of slightly injured car occupants increases. The opposite effect is found in February, October and November with temperature increases leading to decreases in the number of slightly injured car occupants. The April temperature regressor with an estimated coefficient of 0.027 implies that if the temperature in April is 1 °C higher than average this will increase the number of slightly injured car occupants in April by about 2.7%. The model suggests that as rainfall increases in February, March, April, May, June, July, August, September, October, November and December, the number of slightly injured car occupants increases. The largest effect is found for the April regressor with an estimated coefficient of 0.002 which implies that if the rainfall in April is 1 mm higher than average this will increase the number of slightly injured car occupants in April by about 0.2%.

Weather-adjusted road casualty figures

The estimated temperature and rainfall effects from the above time series modelling have been used to produce temperature and rainfall adjusted road casualty figures for the time period 1991 to 2014. These casualty figures represent the number of road casualties we would have expected that year had the temperature and rainfall in each month of the year been at the long term average. The adjustment is illustrated below for fatalities in 2010.

All statistical models are ways of generalising something that is happening in the real world. In this case, we are attempting to model how casualty numbers are affected by variations in temperature and rainfall. This is an imprecise science that collapses detailed local differences in weather across the UK into a single figure. This model, like all statistical models, has a level of uncertainty associated with it. In particular, the analysis used here models how relatively common and regular weather variations influences casualty numbers. It is less good, therefore, at dealing with extreme events or highly unseasonable events. In addition, statistically significant effects have not been found in all months for each road user type and severity. Therefore unusual conditions in some months will not result in any adjustment to the casualty figures. Owing to the uncertainty in the model, these figures should be taken only as our best estimate of what might have happened had the weather during the years been closer to the long term average. There is no way to verify that these outcomes would have happened given different conditions.

Road fatalities weather adjustment: 2010

The table below shows the average temperature and rainfall in the UK for each month in 2010 as well as the average over January 1979 to July 2015. Also shown is the number of killed vulnerable road users in each month. These figures have been adjusted using the estimated temperature and rainfall effects from the vulnerable road user fatality models (see above).

UK rainfall and average temperature in 2010 by month

	Temperature (°C)	Average temperature, 1979-2015 (°C)	Rainfall (mm)	Average rainfall, 1979-2015 (mm)	VRU fatalities	VRU fatalities (adjusted)
JAN	0.9	3.5	79.7	120.0	51	56
FEB	1.9	3.7	74.8	87.6	51	56
MAR	5.1	5.4	79.4	90.7	63	62
APR	8	7.5	48.0	68.9	73	69
MAY	9.8	10.3	39.0	71.2	92	92
JUN	14.2	13.0	38.6	72.9	96	90
JUL	15.6	15.1	107.6	76.7	74	74
AUG	14.2	14.9	97.6	90.1	109	114
SEP	12.8	12.7	114.0	92.0	89	93
OCT	9.4	9.6	101.1	126.3	102	102
NOV	4.3	6.3	123.2	118.0	73	73
DEC	-0.9	4.0	47.5	124.3	46	58
2010	8.0	8.9	950.5	1,137	919	940

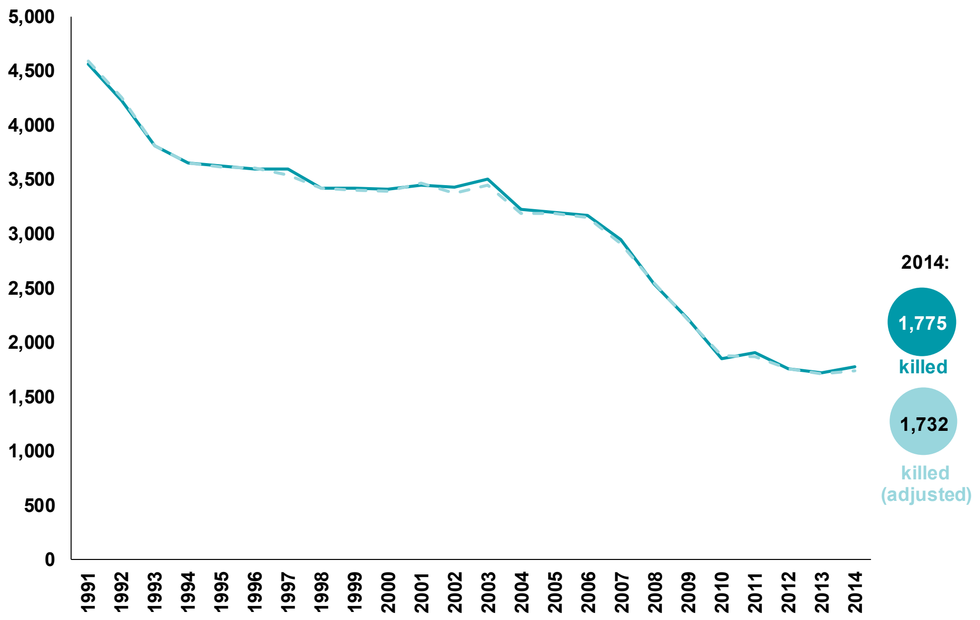
The largest weather adjustment for killed vulnerable road users in 2010 occurred in December. This month was particularly cold which would have led to fewer pedal cyclist and motorcyclists on the roads than would have been expected had the temperature been average leading to a decline in exposure to accidents. The model estimates that if the temperature in December had been average there would have been 2 more pedal cyclist fatalities and 4 more motorcycle fatalities. A positive relationship between rainfall and killed pedestrians was also found in December. It is estimated that the lower than average rainfall in December led to 5 fewer killed pedestrians than would be expected. The December vulnerable road user fatality figure is therefore revised upwards by 12 from 46 fatalities to 58 fatalities i.e. the model estimates there would have been 58 fatalities in December 2010 if temperature and rainfall had been average. Similarly, the model estimates there would have been more killed vulnerable road users in January, February and August, largely due to the colder than average temperatures in these months. The May, July and October fatality figures are unchanged as no statistically significant effect of temperature or rainfall on killed pedestrians, pedal cyclists or motorcyclists was found (see above). The November fatality figure is unchanged as no statistically significant effect of temperature on killed pedestrians, pedal cyclists or motorcyclists was found and the rainfall was close to average so did not have much of an impact on killed motorcyclists.

Overall, the model estimates that there would have been 21 more vulnerable road users killed in 2010 if the temperature and rainfall had been average. The 2010 vulnerable road user fatality figure is therefore adjusted upwards from 919 to 940. Given that no statistically significant impact of temperature or rainfall was found on car occupant fatalities, the 2010 total fatality figure across all road user types is also adjusted upwards by 21 fatalities. This gives a weather-adjusted fatality figure of 1,871 road fatalities in 2010 i.e. we would have expected 1,871 road fatalities in 2010 had the temperature and rainfall been average, compared with the 1,850 actually observed.

Weather-adjusted road fatalities

Applying the above adjustments to all years over 1991 to 2014 and all road user groups gives the following weather-adjusted fatalities series:

Chart 3: Actual and weather-adjusted fatalities in reported road accidents: GB, 1991-2014 ([RAS30080](RAS30080))



The largest weather adjustments for fatalities in the last few years have been in 2010, 2011 and 2014.

2010

In 2010 the temperature was particularly cold, the twelfth coldest year on record. The temperature was well below average in the months of January, February, November and December. Although no statistically significant temperature effect was found for November, the model estimates that the colder temperatures in January, February and December led to 15 fewer vulnerable road user fatalities than would have been expected if temperature had been average. The months of March, May and August were colder than average with April, June and July warmer than average. No statistically significant effect of temperature on vulnerable road user fatalities was found in May, June, July, October or November but the warmer than average April is estimated to have led to 3 more killed vulnerable road users than if temperature had been average. March was slightly colder than average, but the negative impact of colder than average temperature was offset by the positive impact of lower than average rainfall leaving vulnerable road user fatalities unchanged. The colder than average August is estimated to have led to 5 fewer vulnerable road user fatalities than would have been expected had the temperature been average.

Overall 2010 was a dry year with most months having below average rainfall. The rainfall impact on killed vulnerable road users in 2010 is more difficult to explain as the rainfall effect varies between months and between users. A positive relationship between rainfall and killed pedestrians was found in February and December. However, a negative relationship was found for killed pedal cyclists in April and for killed motorcyclists in March, June, September and November. The lower than average rainfall in February is estimated to have led to one fewer killed pedestrian than if rainfall had been average and the lower than average rainfall in December five fewer than if rainfall had been average. The impact of the lower than average rainfall in March was offset by the impact of the colder than average temperature leading to vulnerable road user fatalities remaining unchanged. The lower than average rainfall in April is estimated to have led to one more killed vulnerable road user than expected and the lower than average rainfall in June 6 more. The higher than average rainfall in September is estimated to have led to four fewer killed vulnerable road user fatalities and the rainfall in November was not so far above average to lead to the fatality figure being adjusted. No statistically significant effects of rainfall on vulnerable road user fatalities were found for the months of January, May, July, August and October.

Overall, it is estimated that the colder than average temperature in 2010 led to 19 fewer killed vulnerable road users than if the temperature had been average and the lower than average rainfall to 2 fewer than if rainfall had been average. Therefore, the 2010 vulnerable road user fatality figure is adjusted upwards from 919 to 940. Given that no statistically significant impact of temperature or rainfall was found on car occupant fatalities, the 2010 total fatality figure across all road user types is also adjusted upwards by 21 fatalities. This gives a weather-adjusted fatality figure of 1,871 road fatalities in 2010 i.e. we would have expected 1,871 road fatalities in 2010 had the temperature and rainfall been average, compared with the 1,850 actually observed.

2011

2011 was a warm year with most months having temperatures above average. Temperatures in February, March, April, September and December were above average which led to more vulnerable road user fatalities than would be expected. April 2011 was the warmest April on record which is estimated to have led to 17 more vulnerable road user fatalities than would be expected if the temperature had been average. Although October and November were well above the average temperature, no statistically significant effect of temperature on vulnerable road user fatalities were found in these months. January and August were below the average temperature which led to fewer vulnerable road user fatalities than would be expected. Overall, it is estimated that the warmer temperature in 2011 led to 21 more vulnerable road user fatalities than would have been expected if the temperature had been average.

Overall 2011 rainfall was close to average. However, there were months where rainfall differed significantly from the average. The higher than average rainfall in February 2011 is estimated to have led to 2 more killed vulnerable road users (as a positive relationship was found between rainfall and killed pedestrians). Lower than average rainfall in March, April and November led to more vulnerable road user fatalities than would be expected (11 more over all these months). Higher than average rainfall in June and September 2011 is estimated to have led to 5 fewer vulnerable road users than would be expected and the higher than average rainfall in December to 5 more than expected. Therefore largely due to the dry March, April and November it is estimated that there were 13 more vulnerable road user fatalities than would be expected if rainfall had been average.

Overall, it is estimated that the rainfall and temperature in 2011 led to 34 more vulnerable road user fatalities than would have been expected if temperature and rainfall had been average. Therefore, the 2011 vulnerable road user fatality figure is adjusted downwards from 922 to 888. The 2011 total fatality figure across all road user types is also adjusted downwards by 34 fatalities. This gives a weather-adjusted fatality figure of 1,867 road fatalities in 2011 i.e. we would have expected 1,867 road fatalities in 2011 had the temperature and rainfall been average, compared with the 1,901 actually observed.

The weather-adjusted fatality figure for 2010 is 1,871 and 1,867 for 2011. The 2010 and 2011 figures were particularly affected by the weather (2010 by the cold weather and 2011 by the warm weather) and adjusting for the weather shows that had the temperature and rainfall been average in 2010 and 2011 fatalities would have been unchanged between the two years (4 fewer in 2011).

2012

Across 2012 the temperature was close to average, but it was considerably wetter than average. Unlike most months of the year, March 2012 was considerably drier than average and over 2 °C warmer than average. The warm and dry conditions in this month are estimated to have led to 19 more vulnerable road user fatalities than would have been expected had conditions been average. January and August were also warmer than average leading to more vulnerable road user fatalities than expected. The higher than average rainfall in December is estimated to have increased vulnerable road user fatalities by 6 (as a positive relationship between rainfall and pedestrian fatalities was found). The positive effects on fatalities of these months were virtually offset by the cold and wet April (led to 7 fewer vulnerable fatalities) and wet June and September which led to fewer vulnerable road user fatalities than would be expected. Overall, it is estimated that the temperature and rainfall in 2012 led to 3 more vulnerable road user fatalities than would be expected. Therefore, the 2012 fatality figure has been adjusted from 1,754 to 1,751.

2013

Overall 2013 was close to average for both rainfall and temperature with small adjustments made to the monthly fatality figures. The largest weather adjustments were seen in March and December. March 2013 was the second coldest on record as well as lower than average for rainfall and it is estimated that this led to 7 fewer vulnerable road user fatalities than if temperature and rainfall had been average. December 2013 was warmer and wetter than average leading to 9 more vulnerable road user fatalities than would have been expected (as a positive impact of temperature and rainfall on vulnerable fatalities was found in December). Overall, it is estimated that the temperature and rainfall in 2013 led to 5 more vulnerable road user fatalities than would be expected if temperature and rainfall had been average. Therefore, the 2013 fatality figure has been adjusted from 1,713 to 1,708.

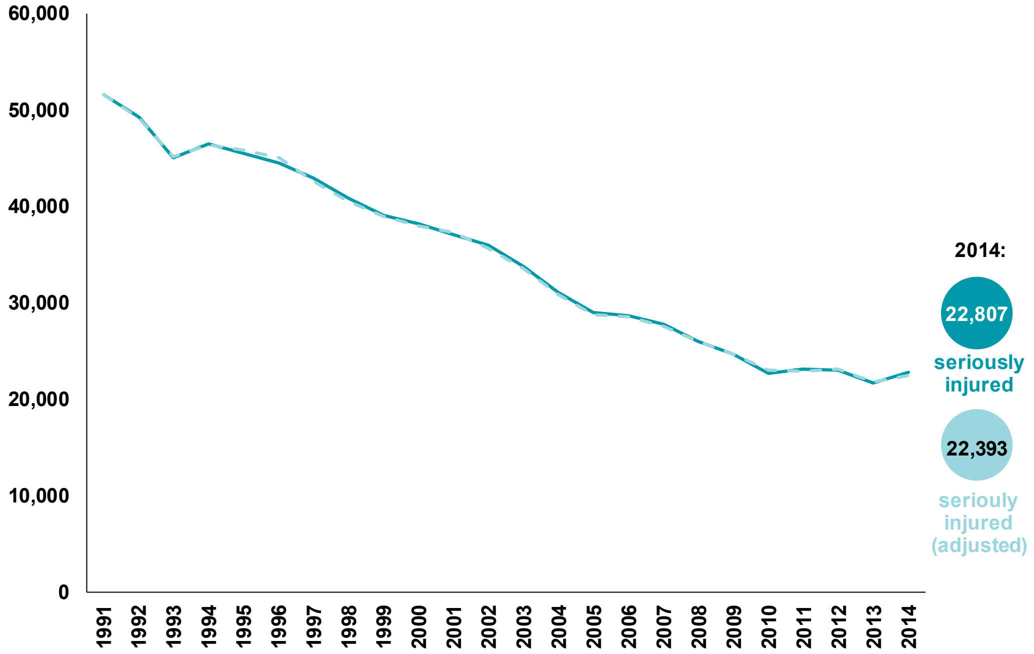
2014

2014 was the warmest year on record as well as the fourth wettest year on record. The months with above average rainfall were January, February, May, August and October, but of these months only February rainfall was found to have a statistically significant impact on killed vulnerable road users. The heavy rainfall in February is estimated to have led to more killed vulnerable road users (as a positive relationship was found in February – see killed pedestrians). September 2014 was the fourth warmest on record and also the driest September on record. The combination of warm and dry weather in September is estimated to have led to 19 more killed vulnerable road users than if temperature and rainfall had been average. Warmer than average temperatures in January, February, March and April are also estimated to have led to more killed vulnerable road users than expected. Largely due to the warmer than average temperatures in 2014 and the warm and dry September, it is estimated that there were 43 more killed vulnerable road users in 2014 than would have been expected.

Therefore, the 2014 fatality figure has been adjusted downwards from 1,775 to 1,732 i.e. we would have expected 1,732 road fatalities in 2014 had the temperature and rainfall been average, compared with the 1,775 actually observed. This suggests that if 2014 hadn’t been so warm, there would still have been an increase in fatalities between 2013 and 2014, but of around 1 per cent rather than the 4 per cent actually observed.

Weather-adjusted seriously injured casualties

Chart 4: Actual and weather-adjusted seriously injured casualties in reported road accidents: GB, 1991-2014 (RAS30080)



The largest adjustments for seriously injured casualties in recent years were in 2010, 2011 and 2014.

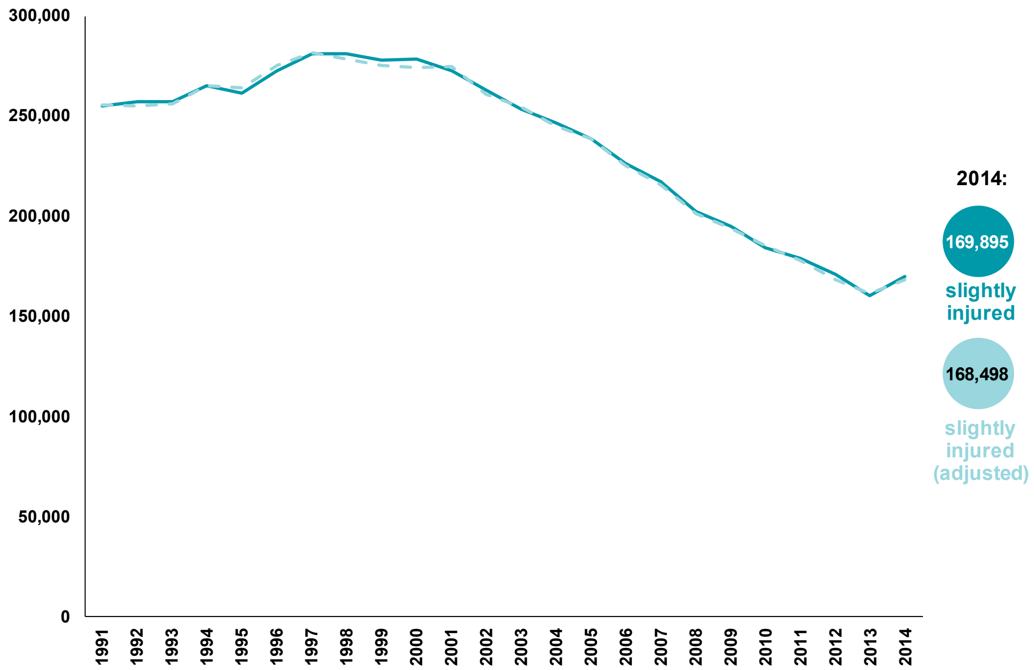
The 2010 seriously injured figure of 22,660 has been adjusted upwards to 22,979 i.e. we would have expected 22,979 seriously injured casualties in 2010 had the temperature and rainfall been average, compared with the 22,660 actually observed. This is largely due to the impact of the colder than average temperature in 2010 on seriously injured vulnerable road users. It is estimated that in 2010 there were 230 fewer seriously injured vulnerable road users than if the temperature and rainfall across 2010 had been average. December 2010 was particularly cold and the model estimates that the cold December had 233 fewer seriously injured vulnerable road users than would be expected if temperature and rainfall had been average.

The 2011 seriously injured figure of 23,122 has been adjusted downwards to 22,836 i.e. we would have expected 22,836 seriously injured casualties in 2011 had the temperature and rainfall been average, compared with the 23,122 actually observed. This is largely due to the impact of the warmer than average temperature in 2011 on seriously injured vulnerable road users. It is estimated that in 2011 there were 269 more seriously injured vulnerable road users than would have been expected if 2011 had been average for temperature and rainfall. April 2011 was particularly warm and it is estimated that in this month there were 168 more seriously injured vulnerable road users than would be expected if temperature and rainfall had been average.

The 2014 seriously injured figure of 22,807 has been adjusted downwards to 22,393 i.e. we would have expected 22,393 seriously injured casualties in 2014 had the temperature and rainfall been average, compared with the 22,807 actually observed. This is largely due to the impact of the warmer than average temperature in 2014 on seriously injured vulnerable road users. It is estimated that in 2014 there were 444 more seriously injured vulnerable road users than would have been expected if 2014 had been average for temperature and rainfall. In particular, the very warm and dry September is estimated to have led to 91 more seriously injured vulnerable road user casualties than would have been expected if temperature and rainfall had been at the average. This suggests that if 2014 hadn't been so warm, there would still have been an increase in seriously injured casualties between 2013 and 2014, but of around 3 per cent rather than the 5 per cent actually observed.

Weather-adjusted slightly injured casualties

Chart 5: Actual and weather-adjusted slightly injured casualties in reported road accidents: GB, 1991-2014 (RAS30080)



Due to the large number of slightly injured casualties, the weather adjustment has little impact on the number of slightly injured casualties and does not change the trend shown in the chart above.

The 2014 slightly injured figure of 169,895 has been adjusted downwards to 168,498 i.e. we would have expected 168,498 slightly injured casualties in 2014 had the temperature and rainfall been average, compared with the 169,895 actually observed. This is largely due to the impact of the warmer than average temperature in 2014 on slightly injured vulnerable road users. It is estimated that in 2014 there were 1,358 more slightly injured vulnerable road users than would have been expected if 2014 had been average for temperature and rainfall.